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EXTRA-OCULAR PRESSURE AND MYOPIA

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EXTRA-OCULAR PRESSURE AND MYOPIA

BY
ISLAY B. MUIRHEAD, M.D.



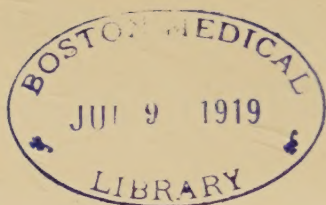
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TO
LAURENCE AUSTINE WADDELL,
IN ADMIRATION OF HIS WORK AS AN ORIENTALIST,
AND TO COMMEMORATE A FRIENDSHIP,
WHICH HAS LASTED SINCE WE WERE STUDENTS TOGETHER
AT GLASGOW UNIVERSITY
NEARLY FORTY YEARS AGO.



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Preface.

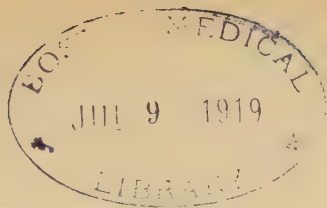
HAVING some years ago called attention to facts militating against current views as to the effect of convergence on the length of the optic axis, I became involved in a discussion as to their bearing on the related subjects of the incidence and treatment of myopia. The discussion, while tending to confuse the original issue, had, from my point of view, at least one good result, in so far as it rather strengthened than weakened my belief in the general soundness of the position, which I had been led to take up. It has lately been revived in a somewhat acute form in connection with the problem of the shortsighted recruit. In

Preface

the circumstances it is hoped that a fuller presentation of the facts may assist others, more especially those who have favoured me with criticisms or confirmations, to arrive at a decision regarding them.

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EXTRA-OCULAR PRESSURE AND MYOPIA.

I

Evidence from Anatomy.

IF we admit that the eye varies somewhat in shape under the varying forces exerted upon it by its surroundings, we shall have to take account of certain optical consequences, which the variations must entail. Similar symmetrical increments or diminutions of the antero-posterior measurements will cause a change of focus like that which would be brought about by placing a spherical lens in front of the eye. Alterations of the cornea or fundus, causing either to assume something of the cylindrical form, will change the focus in the

Evidence from Anatomy

same way as it would be changed by a cylindrical lens. It has long been believed that the effect of muscular pressure during convergence is to cause a tendency to antero-posterior elongation of the eyeball, and that in certain cases the elongation thus originated becomes fixed and leads to myopia. Imported into this country from Germany, and being by frequent reiteration and contrary to all reason gradually elevated into a first principle, the belief has injured ophthalmology by preventing the impartial investigation of the effects of extra-ocular pressure in the light of advancing knowledge. That it still survives in strength was shown not very long ago by the undisguised anger and bewilderment, with which the editor of an eye newspaper listened to my reasons for suspecting it to be to a large extent erroneous.

Evidence from Anatomy

The physiologist, who should examine the ophthalmic anatomy for the first time without prejudice, could hardly fail to be struck by the preponderance of the antero-posterior over the transverse pull upon the globe, and by the likelihood that joint action of the extra-ocular muscles might cause some degree of antero-posterior flattening. In view of the above-mentioned opinion as to the effect of increased pressure during convergence, it was scarcely to be expected that the possibility of such an antero-posterior flattening of the eyeball by the muscles would be recognized by practitioners. All the more surprising was it to find that an oculist, whom I recently consulted with regard to the improvement of distant sight experienced by some myopes while flying, thought that it might be due in part to

Evidence from Anatomy

shortening of the optic axis through increased reflex activity of the recti muscles. A more familiar illustration of antero-posterior flattening is afforded by the start forward of the eye when the long muscles are divided during enucleation. It is impossible to doubt that this movement is due to the sudden cessation of a backward pressure of the globe against the other contents of the orbit. If it be objected that the eyeball, though under antero-posterior compression, is not thereby altered in shape, but, when the pull of the muscles is withdrawn, is merely shot forward like a bullet from a gun by the resilience of the tissues behind it, the reply is that such a view is scarcely compatible with the facts. The compressible character of the globe, considered in relation to the degree of retaining force implied by the movement,

Evidence from Anatomy

suggests that the latter must be owing not solely to the rebound of the tissues, but in part also to the elasticity of the eyeball itself. If, then, the tonicity of the muscles in a patient under chloroform produces an appreciable antero-posterior compression of the eye, is it not reasonable to assume that during voluntary movements the pressure will under certain circumstances be increased, and will lead to further axial shortening?

The state of parallelism with forward direction of the optic axes being, according to present views, the rest position of the eyes, is unlikely to involve a materially greater compression than that which is produced by tonicity. Seeing that this is the ordinary direction of the axes in distant vision, the eyes, when focussed for distance, may be assumed to be for the

Evidence from Anatomy

most part under a minimum of antero-posterior compression. In near vision, on the other hand, which is admitted to be an active condition dependent on the co-operation of several muscles, we may expect that there will be an increase of the normal tonicity pressure, and our business in the present section will be to consider how far this expectation is confirmed by study in detail of the dynamics of convergence.

According to the common view the main originator of the changes in the shape of the eyeball, which near work is held to induce, is excessive contraction of the rectus internus muscle. In opposition to this idea I have suggested that the primary cause of augmented pressure during convergence must be increased tension of the rectus externus, produced by the

Evidence from Anatomy

stretching to which it is subjected when the eye is interned.* Were there no such increase of tension, the eye, when turned to the required convergence angle, would remain there with the muscles in the same state of rest as in antero-posterior parallelism of the optic axes. As things are, the internus must continue to contract so long as the interned position is maintained, in order to balance the augmented tension of the externus ; and the other two recti come into action simultaneously, to assist the interning movement, and obviate the astigmatism which would result from an increased pull affecting the transverse meridians only. Thus a *prima facie* examination of the forces engaged seems to

* I have ventured to use the verb "intern" and the substantive "internation" as convenient and almost indispensable variants of "converge" and "convergence."

Evidence from Anatomy

indicate that near work will lead to an increase of antero-posterior pressure, and to a shortening of the converged as compared with the unconverged optic axis. While this is so, it is obvious that both in convergence and non-convergence forces are at work which counteract antero-posterior pressure, and may appreciably affect the focus. The chief of these are the transverse components of the pulls of the superior and inferior recti and obliqui muscles, about which it is necessary to say a few words.

Some of those who believe that the effect of the muscles during convergence is to cause a tendency to elongation, have attributed a special influence of this kind to the obliquus superior. In my view it is necessary to regard both obliqui as contributing in certain circumstances towards

Evidence from Anatomy

antero-posterior lengthening. When we examine the line of action of these muscles as drawn in the text-books, we see that it crosses the globe in a diameter slightly nearer the transverse than the antero-posterior axis. Hence the effect of the obliqui, did they always pull in the manner suggested by the drawings, would be to produce some small measure of transverse compression of the eyeball, the resistance countering the traction of the muscles being in this case partly the hold on the globe maintained by Tenon's capsule, and partly the internal wall of the orbit with the tissues between it and the eye. Seeing, however, that the text-book delineations apply only to antero - posterior direction of the axis, and that other directions would evidently establish a different relation of the pull to the ocular diameters,

Evidence from Anatomy

we have to consider how the effect of the obliqui will vary in other and more especially in converged positions of the eye. When the eye is directed inwards as in ordinary binocular vision at from twelve to fifteen inches distance, the pull of the obliqui, instead of being nearer the transverse than the antero-posterior diameter, will be found, as in the accompanying diagram,* to be slightly nearer the antero-posterior than the transverse diameter. In near work therefore action of the obliqui, so far from compressing the globe laterally, tends to compress it antero-posteriorly and to produce a measure of axial shortening.

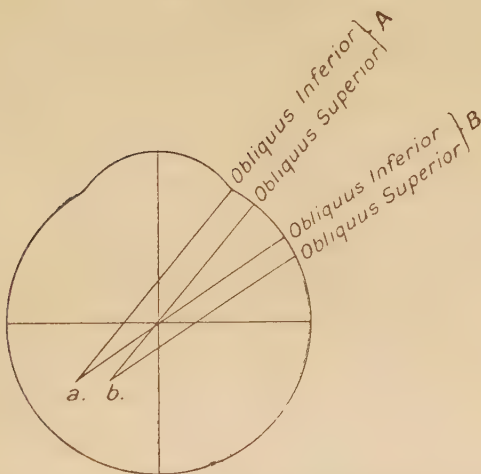
A second factor modifying the effect of the obliqui is varied location of the eye-

* For clearness' sake the diagram somewhat exaggerates the changed relationships.

Evidence from Anatomy

ball, an advanced position in the orbit giving a more transverse and a backward position a more antero-posterior

Left Eye.



Pull of obliqui muscles, A. in convergence, B. in parallelism of the visual axes. Small a. and b. are the positions of attachment below and above the eyeball of the obliquis inferior and superior respectively.

pull. Since the elongation of myopia is usually rather forwards than backwards, the obliqui commonly cross the globe

Evidence from Anatomy

more transversely in the short-sighted than in others ; in keeping with which peculiarity it is found that their lines of insertion into the eyeball have a more antero-posterior and less transverse direction in the myope than in the emmetrope or hyperope.* Hence in the myopic eye, and in the eye which, though not myopic, occupies a more than usually advanced position, the pull of the obliqui may take a direction nearer the transverse than the antero-posterior diameter even when the eye is interned, and, when such is the case, will tend to produce transverse compression in converged as well as in unconverged positions. Conversely an eye which is short and deeply placed in the orbit, may quite possibly have its

* Observation of E. Fuchs quoted by J. Herbert Fisher, at pages 71-72 of his " Ophthalmological Anatomy."

Evidence from Anatomy

antero-posterior diameter shortened by the obliqui both in converged and unconverged positions of the axis.

Turning to the superior and inferior recti muscles, a glance at the text-book drawings shows us that the effects of changed positions upon their pulls are in general the reverse of those which are produced by the same changes upon the pulls of the obliqui. Internation of the optic axis, which causes the obliqui to take a more antero-posterior course, causes the recti to cross the eyeball in a more transverse direction. Divergence of the axis, while it makes the course of the obliqui more transverse, makes that of the recti more antero-posterior. Advance of the globe, while leading to a more transverse pull of the obliqui, renders that of the recti more axial. Recession of the eyeball, which

Evidence from Anatomy

is attended by a more antero-posterior pull of the obliqui, causes a compensating more transverse pull of the recti. So far then as movements of the eyeball round the vertical axis, or in a straight line forwards or backwards are concerned, it is evident that the changes which they produce in the pulls of the obliqui are balanced by accompanying reversed changes in the pulls of the recti superior and inferior. It follows that mere internation of the eye will not give an advantage to either the transverse or the antero-posterior components of the resolved forces. On the other hand inward movements of the globe will cause the pulls of both recti and obliqui to take a more antero-posterior direction, and will tend to an increase of axial compression. Summing up, we may say that whilst in the case of both the recti and the

Evidence from Anatomy

obliqui muscles we have to take account of both transverse and antero-posterior pressures, there is in all positions of the eye a preponderance of the latter over the former; that the preponderance is increased by conditions which cause either set of muscles to pull in a more antero-posterior and less transverse direction; and that it is greater in convergence than in parallelism of the axes, partly on account of the greater activity of the muscles in near adaptation of the eyes, and partly owing to the slight inward displacement of the globe, to which all active movements of convergence give rise.

Apart from their effect upon the length of the axis, the direction of the pull, and the position of insertion of the recti muscles, suggest that they may cause alterations of the focus by modifying the

Evidence from Anatomy

shape of the crystalline lens. The recti insert into the sclerotic by tendons which are closely connected with one another all round the eyeball. The average distance of the insertions from the cornea is about three-and-a-half lines, and the distance appears to be neither appreciably diminished in the small hyperopic, nor appreciably increased in the large myopic eye. The pull of the recti, backwards as regards the eye as a whole, is to some extent eccentric with regard to the cornea and lens, whilst owing to the firm attachment of the suspensory ligament to the choroid, and the union of the latter by fibrous trabecular with the sclerotic, the traction of the muscles on the sclerotic is transmitted in part to the lens, and seems calculated to produce a degree of flattening of its surfaces. Further, any lateral expansion,

Evidence from Anatomy

which may be associated with the antero-posterior shortening of the globe by the extra-ocular muscles, would increase the eccentric pull on the suspensory ligament and tend to further flattening of the lenticular surfaces. It would clearly be extremely difficult to distinguish in a precise way between the effect of axial shortening and the effect of flattening of the lens, but facts that have been brought to my notice whilst experimenting, suggest that slighter actions of the extra-ocular muscles vary the focus mainly by shortening the axis, but that changes of the refraction system, associated with more powerful actions, are produced by variations of the antero-posterior diameters of both the eyeball and the lens.

I have called the above effects of muscular pressure a "natural correction of my-

Evidence from Anatomy

opia " and shall show later that the phrase has a certain convenience in connection with both the defects and the development of the eye. Meanwhile it must be admitted to be somewhat opposed to the myopia-correction theory that, under ordinary circumstances, the pressure is greatest in converged positions of the axes, in positions, that is to say, in which it is least needed. In mitigation of the anomaly it has been suggested that we may have here a provision for lessening the rapidity of the changes of focus from near to distant and vice versa. Apart from such an arrangement the changes would be so rapid that the eye might have difficulty in noting the attainment of the focal point. The convergence shortening and divergence elongation, working against the action of the lens, diminish the abruptness of the

Evidence from Anatomy

subjective adjustments, and enable the eye to light easily and accurately on the focal point. The importance of this with regard to aiming is evident, and it is surmised that the power may have been acquired at an early stage of man's development when his subsistence depended more than it does now upon bringing down enemies and game at a distance. While not denying that these ideas may contain an element of truth, I am bound to say that they seem to me to imply a more considerable pressure shortening of the axis than the facts as at present known render probable.

Evidence from Changes in

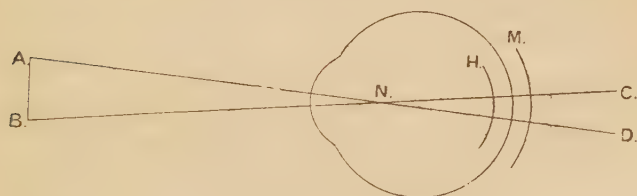
II

Evidence from Changes in the Apparent Size of Objects.

THE following diagram, for which I am indebted to Mr. E. Edser, Head of the Physics Department, Goldsmiths' College, University of London, represents the so-called "reduced eye," the eye, that is to say, in which the lens is got rid of, and the refractive power is concentrated in a cornea of exaggerated curve. A single point N does duty for the nodes of both cornea and lens. AD and BC are rays from the extremities of the object AB, which pass unrefracted through N to the retina. The eye is emmetropic, and the positions H and M of the hyperopic and myopic retinæ show

the Apparent Size of Objects

how the retinal image would diminish or enlarge, were the eye to shorten and elongate under the influence of varying strains of the extra-ocular muscles. If the optic axis is shortened during convergence, adaptation for near vision will, *cæteris paribus*, cause diminution of the retinal



images. If the axis elongates during convergence, near adaptation will cause enlargement of the retinal images. If convergence makes things appear larger, the presumption will be that it is attended by elongation of the optic axis; if it causes apparent diminution of objects, the fact will evidence a convergence shorten-

Evidence from Changes in

ing of the optic axis. As authorities are unanimous in asserting that near work tends to produce antero-posterior elongation, we naturally look for a like unanimity in favour of a convergence enlargement of the retinal images. What we find among those who have given attention to the subject is that, almost without exception, they maintain that near adaptation of the eyes is associated with apparent diminution of objects. They point out, for example, that an undercorrected hyperope or presbyope, who looks steadily at near objects, is soon aware that they appear to have grown smaller ; that an emmetrope, supplied with prisms turned base outwards, and therefore compelled to converge beyond the normal angle for near vision, notices a seeming minification of the contents of both his near and distant fields. I will

the Apparent Size of Objects

show presently that this notion of near adaptation of the eyes being universally, or even generally, a cause of apparent diminution, is an error due to obsolete experimental methods. What I would meanwhile emphasize is that the notion has been widely entertained, and would long ago have proved fatal to the convergence elongation theory, had it not been for another theory, which, coincidentally with the belief in near-work elongation, and, it must now be added, with a like absence of any sufficient basis in facts, began to be favoured by authorities, and which it is necessary to examine briefly.

It was said that the diminutions attending near adaptation of the eyes were not due to a change in the retinal images, but were apparent only, and resulted from association between varying strains of

Evidence from Changes in

the ciliary and recti interni muscles, and varying distances of objects from the eyes. When the strain increased, things were imagined to be nearer than they were in reality, and, as no increase of apparent size occurred, were credited with diminishing by an amount, which bore some kind of proportion to the amount by which they ought to have increased, had they been approximated to a distance conformable with the altered strain. When the strain diminished, objects were imagined to have receded to the point indicated by the lessened strain, and, as no actual diminution took place, were supposed to have grown larger to an extent in some measure proportioned to the shrinkage which they should have undergone, had they been removed to a distance corresponding to the diminished muscular effort.

the Apparent Size of Objects

By this curious process of unconscious inference we were taught, and, for my part, until some few years ago, I continued to believe implicitly, that nearly all the variations of apparent size which accompany varying adaptation of the eyes, but are unattended by demonstrable change in the size of the retinal images, had arisen and were to be explained.

When we test this ingenious theory by present-day methods, what soon strikes us is that the changes, which it alleges to result from varying adaptations of the eyes, are in many cases precisely the reverse of those, which actually take place. If we take people as they come without selection, and cause them to look at near objects first in the ordinary way, and then with convergence relaxed, that is, with the visual axes deviated beyond the

Evidence from Changes in

binocular position, we find in the majority of cases that if a difference is detected, the double images of relaxed convergence are recognized as being smaller than the single image of converged vision. Diminution of convergence is found, that is to say, to produce the effect which, according to the theory, should be produced by its increase. So complete a reversal of an accepted cause relationship suggests that the facts may be somewhat more complex than has been supposed. One thinks of the magnification of objects by convergent lenses, and of that which has been observed to accompany spasm of the ciliary muscle, and is led to ask whether accommodation may not be a cause of enlargement rather than diminution of apparent size. Were this so, and did convergence effect the apparent dimi-

the Apparent Size of Objects

nution with which it is credited, we can readily imagine that the enlargement due to accommodation would at times exceed and at times fall short of the minification arising from the convergence with which it is normally associated, and so account for the contradictory results of experiments. The diminutions in the cases of the under-corrected hyperope and presbyope would then be caused, not by excessive but by deficient accommodation. The ciliary muscle, exhausted by the struggle with adverse conditions, gradually ceases to contract, and the retinal images diminish in size with the diminishing convexity of the lens.

To see whether this is so or not, let us consider not the average man, but the exception ; cases, that is to say, in which near objects are seen without accommoda-

Evidence from Changes in

tion. Two instances at once suggest themselves, the 3D myope, who does not wear a correction, and the presbyope who reads with a + 3D lens. I have made no experiments with the latter, but with regard to the uncorrected 3D myope, after doing a great many experiments, I have no hesitation in asserting that in his case the double images of near objects, seen when convergence is relaxed will, almost without exception, be found to be larger than the single image of converged binocular vision. Taking this fact in connection with the diminution under like circumstances in the emmetrope, we can, I think, come to no other conclusion than that the difference is due to the absence in the uncorrected myope of accommodation, which in the emmetrope eliminated, and replaced by magnification, the minifi-

the Apparent Size of Objects

cation otherwise normally associated with adjustment for near vision. That this is in fact the cause of the difference, is made evident by two other observations which I have frequently had occasion to make.

If we supply the uncorrected myope with glasses, and, having given the eyes time to adapt themselves to the new conditions, make him as before, while looking at something close at hand, deviate the eyes beyond the binocular position, and then say whether the single image of convergence or the two images of unconverged vision are larger, if he gives a definite answer, he will almost always be found to declare in favour of the single binocular image. The divergent lens had caused him to accommodate involuntarily, and the magnifying effect of accommodation, exceeding the minifica-

Evidence from Changes in

tion of convergence, made the single converged image larger than the two images of non-convergence. Conversely, if we supply the emmetrope with a 4D convergent lens, we are able in a good many cases to annihilate accommodation, and place him in a position resembling that of the uncorrected myope. When we succeed in doing so, the effect of the relaxation experiment is, in his case, the same as in the uncorrected myope, the double images of unconverged vision seem to him larger than the single binocular one. Whilst these observations show an effect of accommodation differing from that which has been traditionally ascribed to it, they imply that inward direction of the eyes, did it operate alone, would always be attended by apparent minification of objects.

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Turning from the outward to the inward squint, we find in almost all states of the refraction, and whether glasses are worn or not, a steady diminution of the double convergence images of near objects the further the inward movement of the axis is carried. The universality of apparent diminution on converging in excess of the requirements of ordinary near work suggests that accommodation does not, as a rule, operate inside working distance, or, at least, that the degree in which it operates no longer keeps pace with the increase of convergence as it does in adaptation for distances outside that of customary work. Not only is the convergence diminution more obvious inside than outside working distance, it is also more considerable in amount. Whilst we have no means of estimating it with pre-

Evidence from Changes in

cision, I have come to believe, as the result of experiments done both on myself and others, that the diminution associated with convergence from parallelism of the visual axes inwards to working distance is about half as great as that effected by convergence from working distance inwards to its extreme limit.

Although the effects of squinting upon apparent size have not, so far as I know, been ever investigated before, it would not be true to say that no one has previously attempted to distinguish between the parts played by accommodation and convergence in bringing about the apparent changes of size, which accompany near and distant adaptation of the eyes. A good many years ago Mr. N. Bishop Harman published an interesting series of observations which showed, in his

the Apparent Size of Objects

opinion, that the share taken by ciliary strain in the minifications of near work is a comparatively minor one, and that the essential agency in effecting them is the effort of the internal recti muscles during convergence.*

Putting Mr. Harman's results beside my own, we may say that the most recent experiments bearing upon near-work diminutions of apparent size tend to disconnect them from accommodation, and to connect them more intimately than

* On submitting this passage to Mr. Harman, he wrote under date March 10, 1916: "The note you enclose is a fair statement of my results. I am only inclined to diffidence in putting the whole effect down to the action of the internal recti; for in convergence the other muscles take part—certainly the superior and inferior recti—and then there is the necessary controlling action of the external recti muscles. It would therefore, be better to say, 'the controlling action of the extra-ocular muscles.'"

Evidence from Changes in

ever before with convergence. While doing so they, at the same time, increase the difficulty of maintaining the associative origin of the diminutions. The admission, that is to say, that accommodation, which is the essential agent in near vision does not produce an associative minification, establishes a strong presumption against the production of such a minification by convergence, whose connection with near vision is, after all, a comparatively slight and, so to speak, a merely accidental one. Even were the part taken by convergence in near adaptation the leading one, the squint experiments would still raise serious doubts as to the truth of the traditional theory. While the theory implies that convergences for equal approximations should be associated with approximately equal diminu-

the Apparent Size of Objects

tions, we have proof of the complete absence of any such association in the above noted fact that convergence from parallelism to the near-work angle does not produce more than about half the minification effected by convergence from the working position to that appropriate to a three-inch distance from the eyes. Finally, and quite apart from the difficulty of its excessive amount, the latter minification brings us face to face with the question as to how associations could be established without any, or with hardly any, of the experiences which form their indispensable basis. Whilst it is no doubt possible for people with exceptionally strong muscles to view objects binocularly for considerable periods under the high strains, which distances of a few inches entail, mankind generally are

Evidence from Changes in

fortunately not in the habit of looking at things in this way, and can have derived no racial associations from such misuse of their eyes.

Among Mr. Harman's experiments is one in which diminutions comparable, and, perhaps to some extent identical, with the inward squint diminutions, are obtained without any convergence of the observing eye, and are considered by him to be due to convergence of the other eye which is occluded. Having covered one eye, Mr. Harman sits in front of a mirror, and holding a finger at arm's length at first, gradually approximates it to the other observing eye, which is kept focussed upon it during the movement. The effect of this proceeding is to show a steady diminution of the reflection of the observer's face in the mirror, the face

the Apparent Size of Objects

seeming at the same time to move further away *pari passu* with the approximation of the finger. While Mr. Harman's explanation of these appearances may quite possibly be the true one, we ought, as it seems to me, to exhaust other possibilities before admitting so remarkable a theory. To me it rather seems that a part, at least, of the apparent change of size may be due to a slight shortening of the axis of the observing eye. To look at an object, as the finger is looked at in the experiment, is a somewhat unnatural mode of vision. The natural way is with both eyes interned, and with the object at least a foot from the eyes. To keep the observing eye directed straight forwards, while the other is more and more strongly interned, involves strong innervation and powerful contraction of the external rectus

Evidence from Changes in

muscle of the unoccluded eye. Hence the eye might be expected to shorten under the strain of the unnatural position in the same way as it shortens in normal near vision with converged axes. That internation of one eye does not ordinarily cause apparent diminutions of objects as seen by the other is well illustrated by the following experiment. If we follow with the eyes an object which is gradually moved from the front position to a position considerably to one side, and then, while still looking at the object, first converge and then unconverge the eyes beyond the binocular position, it will be found that both in the outward and inward squint the one eye is always more or less interned, while the other is never interned at all. The effect, however, upon the size of the images is this. In binocular vision

the Apparent Size of Objects

it remains unaltered however far to one side the object is carried. In squint vision, whether the deviation be inwards or outwards, the image seen by the interned eye is markedly smaller than that seen by the non-interned one. While the image seen by the former is always appreciably smaller than the binocular image, that seen by the latter is invariably of about the same size as the single primary. Did internation of one eye cause apparent diminution of objects as seen both by it and by the other eye, we should expect that there would be some diminution of the size of the binocular image during the lateral movement, and that the size of the image seen by the non-interned eye during the convergent squint would be appreciably smaller than the binocular image. As neither expectation is realized, the experiment suggests

Evidence from Changes in

that in normal vision the apparent size of objects seen by an eye depends on the converged or unconverged state of that eye, and has no relation at all to convergence or non-convergence of the other eye.

Upon the whole it does not seem to me likely that the diminution and recession of objects in Mr. Bishop Harman's experiment are due in any material degree to internation of the occluded eye. While looking upon both changes as, perhaps, explicable in part by a shortening of the optic axis, I believe that in the main they are due to a quite different cause from that of the diminutions in my squint experiments. In a word, I suggest that they may be optical illusions of the same kind as occur at a railway station when one's train has begun to move; and

the Apparent Size of Objects

although from the vibration it is quite obvious that it is moving, one, nevertheless, has the impression that a train on the next line which is standing still is moving in the opposite direction. The diminution in Mr. Harman's experiment would on this view be an associative one. The real enlargement of the finger image gives rise to the impression that other objects in the field are growing smaller, and this apparent diminution produces by association the further illusion that they are receding from the observer.

Evidence from Change in

III

Evidence from Change in the Definition of Objects.

THE diminution of apparent size caused by convergence from parallelism to the near-work angle seems to be about the same as that which is produced by a half-dioptre divergent lens. As such a lens alters the definition of objects appreciably, we should expect, on the assumption that the convergence diminution is due to a change of focus, that it would be accompanied by a like change of definition. The question as to whether it is, or is not so accompanied is a complicated one, and may be considered from both the experimental and the clinical view-point. To

the Definition of Objects

make the evidence I have to offer from the former intelligible, it is necessary to state in advance that I am sixty-two years of age, have a myopia of about one and three-quarters dioptries in each eye, and have never worn a correction for near work. The general result of the experiments is to show that sight is improved in myopia and deteriorated in other conditions by a hitherto unnoticed factor associated with the act of convergence, and to suggest that this new factor must be a change of focus, this being the only agency capable of producing the double effect.

In the first place I can improve my uncorrected distance vision in a marked way by squinting inwards. By this means I have frequently been able to read distant letters, which I not only

Evidence from Change in

could not read, but could with difficulty recognize to be letters at all, when looking at them in the ordinary way.

Secondly, when + 3D lenses are placed in front of both eyes, I have to bring objects to a proximity of about six inches in order to see them distinctly. On being removed to seven inches they become hazy, but are cleared by squinting inwards.

To understand these results we have to bear in mind that convergence is attended by contraction of the pupils, by a change in the incidence of the retinal images, and by a measure of involuntary accommodation, which, although less in the uncorrected myope than in others, takes place to some extent even in his case. Of these changes the two latter tend in both experiments to make things less

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distinct, the one, by causing the images to fall on less sensitive parts of the retina, the other by aggravating the myopia ; while the diminution of the pupils materially improves vision by cutting off the outer less accurately refracted rays. If then we assume that convergence is in some hitherto unsuspected way improving the focus, then the extent of that improvement will be found by adding to the apparent improvement an amount sufficient to counterbalance the deterioration due to superfluous accommodation and displacement of the images from the maculæ, and subtracting from it an amount equal to the improvement from pupillary contraction. That the assumption is justified is shown pretty clearly by what occurs when I make use of my correction.

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Putting up — 1·5D lenses, and removing the object to about twenty-two inches, the nearest point at which I can then see it distinctly, I find the two images of strong convergence slightly less well-defined than the single binocular one. That the loss of definition cannot in this case be due to increased accommodation is proved by my inability, whilst wearing the divergent lenses, to see things distinctly at any less distance than twenty-two inches from the eyes. Did increased convexity of the lens accompany the squint convergence it would accompany fixation convergence and give clear binocular vision up to the ordinary working distance of twelve or fifteen inches. We have then to consider only pupillary contraction and displacement of the images, and it would

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be difficult indeed to believe that the dimming from displacement should more than counterbalance the improvement from diminished aperture and account for the deterioration of the corrected myope's near vision by the inward squint. I may here say parenthetically that my experiments lead me to suspect that the superiority of the macula to other parts of the retina as regards clearness of the images is not nearly so great as is commonly supposed. So far from there being always the marked superiority that is asserted, I believe that in a good many eyes the definition both inside and outside the centre of the fundus is at least as good as the definition at the maculæ. A further experiment in which the dimming takes place without displacement of the images shows that

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convergence brings into operation a factor which is capable by itself under certain circumstances of more than neutralizing the gain in clearness from pupillary contraction.

If, having occluded one eye, and placed in front of the other a lens equal in strength to the strongest divergent lens that can be overcome binocularly at working distance, I then, without altering its distance, move a near object into positions requiring more and more convergence of the observing eye; I now obtain a steady lessening of definition the further the movement is carried. The reader will remember that in considering the size of the images in lateral direction of the eyes, the image seen by the interned eye is always smaller than that seen by the non-interned one, and

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that the diminution proves the absence of increased ciliary action. In the present case therefore, we may feel quite certain that no increase of accommodation in the observing eye accompanies the increasing convergence. As there is also no displacement dimming we seem driven to conclude that the loss of definition as the object is moved sideways is due to a hitherto unnoticed factor associated with the interning act.

Experiments like the above lead naturally to an examination of present methods of treating myopia, which, in view of the varied means employed, can be regarded as nothing else than a huge experiment with reference to the comparative merits of opposite systems. Differences of such immense practical moment might have been expected to

occasion some degree of uneasiness among practitioners. As a matter of fact they have been scarcely noticed. If thought of at all, they seem to have been looked upon as very much what was to be anticipated from the application to varying circumstances of well-known ophthalmic principles. We have to consider how far this account of them is correct, and how it has come about that principles, which are held to be indisputable, can in practice work out such contradictory results.

Taking six typical authorities as they present themselves without any selection, I find that their views as to the proper way to deal with moderate myopia occurring in the young adult* are as follows. Three prescribe complete

* Aged 16 to 20.

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correction to be worn always. One gives spectacles correcting from half to two-thirds of the error to be worn always. One corrects fully but directs that the glasses be used for near work only ; and one orders separate glasses for near and distant work, neither of which corrects fully. Considering the prepossessions with which they set out, the wonder is not that so many of these writers advocate full correction as that any of them should be found departing from that rule. Not without significance is it that one of the advocates of full-power spectacles hails from Germany, where the convergence elongation idea has had its most convinced adherents, and that the writer who dwells most on the disadvantages of full correction is an optician, and so perhaps less prone than the others

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to allow his practice to be influenced by merely theoretic considerations. It is remarkable also that none of the advisers of full correction supports his recommendation by any reference to convergence elongation. On the other hand, those who depart from what seems to be regarded as strict orthodoxy in this matter find it necessary to explain their lapse, and for the most part do so in the following way. They say that the uncorrected myope has become accustomed to using convergence in excess of accommodation, and that to compel him to discontinue the habit to the degree entailed by full correction would lead to eyestrain. Seeing, however, that the habit was originally acquired through departing from the natural association between convergence

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and accommodation, one would imagine that recovery of the natural association ought not to be very difficult, so that the explanation, though still finding a place in the text-books, in my opinion gives a very inadequate account of the danger attending full correction.

More obvious than the eyestrain of the fully-corrected myope, is the difficulty experienced by many short-sighted persons in getting a clear view of near objects whilst wearing their spectacles. In my own case the difficulty is present to such a degree that, notwithstanding much painstaking effort, I have never at any period of my life been able to read a single line of small print at working distance through — 1·75 D lenses. Here again the theory that the inability is due to disparity between convergence and

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accommodation breaks down completely in the light of the experimental worsening of the corrected myope's near vision by the inward squint. Were this the true explanation of the difficulty, the increased accommodation which is needed, but which is supposed to be prevented from taking place by the fixed state of the convergence, would be brought into action by the inward squint, and vision would be improved instead of being deteriorated, as it actually is.

On the other hand, if we suppose that a "natural correction" is added during convergence to the effect of the spectacles, we get, as it seems to me, a fairly adequate explanation, both of the sight difficulty and of the eyestrain of the fully corrected myope. The retinoscopist is wont to estimate errors of

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refraction with the optic axes in the antero-posterior position. If therefore he corrects fully, he will have over-corrected for near work by the amount represented by any shortening of the axis which convergence may occasion. Let us suppose the shortening to be an eighth of a millimetre. The patient will now be artificially hyperopic during near vision by rather more than a third of a diopetre. We know that even in those who are accustomed to that state of the refraction, such an amount of hyperopia may cause appreciable eyestrain, and need feel no surprise that in the case of the myope, who is used to the opposite condition, the difficulty produced by so apparently trivial an artificial hyperopia should in many instances be very marked. We should bear in mind also, that the myope

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may be in the habit of instinctively exaggerating the convergence shortening of the axis, that correction induces an active effort of accommodation, and that both circumstances tend to augment eye-strain by heightening the opposition between the concentric pull of the ciliary muscle on the choroid, and the eccentric pull of the recti on the sclerotic. When to these considerations we add the weakness of the myope's accommodation, we can easily understand why in a good many instances it is impossible to get him to wear a full distance correction, and why in those who have overcome the initial difficulty of seeing near objects through their glasses, fatigue and eye-strain frequently make their appearance later. Thus the theory of convergence shortening at once confirms the views of

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those who under correct, and shows why undercorrection must always yield better results than any other treatment, and thus conversely practical ophthalmology by its partial realization of the inadvisability of full correction lends unconscious support to the new theory.

Before leaving this subject it may be proper to add a few words in anticipation of a somewhat obvious criticism. Those who have given attention to convergence diminutions of apparent size may have a not unreasonable doubt as to whether they can be due to the comparatively small changes of focus, with which they appear to be associated. The marked diminutions of the strong inward squint, for example, would seem to imply a greater disturbance of the focus than I have found accompanying them.

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Thinking of the disproportion, it has occurred to me that a possible explanation may be lessening of the retinal elements covered by the image as the eyeball flattens under increased muscular pressure. The flattening of the fundus, combined perhaps with some eccentric expansion of the retina during convergence, would produce such a lessening, whilst relaxation of the pressure, by increasing the curve and allowing a concentric movement of the retina, would increase the number of nervous elements included in the image. As apparent size depends on the number of retinal cones covered by the image, it would according to my hypothesis diminish with the increased pressure of convergence and increase when that pressure is relaxed. Thus part of the diminution of near

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adaptation would be the direct result of the change of focus and part would be due to the accompanying abstraction of cones from the visual area, and the excess of minification over what might reasonably be attributed to the focal change would receive a satisfactory explanation. Precisely how much of the diminution may be due to either factor we do not at present know. That the whole of it cannot be accounted for by the retinal change is obvious from the fact that, were it not for the variation in the shape of the eye, no alteration in the number of cones covered by the image could take place.

Evidence from Etiology

IV

Evidence from Etiology.

STATISTICS show that short-sight may be caused or aggravated by low states of nutrition; that it increases during wasting illness, and diminishes as strength is regained; that city dwellers are much more liable to the defect than country dwellers, the highly civilized than savages, people of sedentary lives than workmen, women than men. In a word, everything that is known with regard to the incidence of myopia shows that it is to some extent a result of weakness. If then we allow that muscular pressure has a share in maintaining the shape of the eyeball, we need have no hesitation in believing,

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provisionally, that one cause at least of the connection of short-sight with weakness is slight elongation of the optic axis arising from the loss of tone in the ocular muscles, from which we know that weakly persons are apt to suffer.

In seeming contrast to this general association of myopia with weakness, is the unanimity with which authorities maintain that strong action of the ocular muscles accompanying convergence is a cause of short-sight. Is this opinion an error, or is it possible that, while strong action of muscles in general protects from myopia, the strong action associated with convergence may predispose to it? In the latter event does convergence act by accumulation and fixation of small increments of the antero-posterior diameter produced by the interning act ; or may

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long-continued near work lead in some unknown way to myopia, notwithstanding that the act of convergence causes antero-posterior shortening? Bearing upon these queries we may recall that short-sight rarely increases after the twenty-fifth year however much near work is indulged in ; that many savages, for example the Esquimaux in their snow huts in winter, make what a school medical officer would certainly consider excessive use of convergence under extremely bad light conditions, yet do not suffer from myopia ; and that neither clinical nor experimental observation has hitherto supplied an instance in which, when accommodation was effectually eliminated, increase of convergence either aggravated an existing myopia or caused an apparent enlargement of objects. It should be noted also in the present

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connection that the anatomical facts frequently put forward in support of convergence elongation are much rather illustrations of the way in which near work might conceivably produce its alleged effects, than proofs that these effects are actually produced. Some of them, for example the weak fundus leading to posterior bulging, traction by the rectus internus in front, and by the optic nerve in the rear, are clearly pathological conditions and can have nothing to do with the physiological myopia, with which we are here concerned. With regard to a factor much insisted on by some, the alleged want of the same support to the fundus as is afforded to the sides of the eye by the long orbital muscles, it may be observed that the fundus is supported by the tissues between the globe and the

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contracting muscles, and that this support being, like the lateral pressure on the globe, proportional to the strength of the backward pull, seems calculated to prevent elongation of the eye even when the fundus is weakened by disease. The really unsupported part of the eye is the part in front of the attachment of the long muscles, and here it is, if anywhere, that we might look for a pressure bulging, did pressure tend to elongate the axis. A good many measurements of the curvature of the cornea have been made, and seem to show conclusively that in myopia the curve is somewhat less than in other states of the refraction. Nature as if foreseeing the danger to which this part would be exposed by the strong pressure of binocular vision, has provided against it by doubling the ocular tunic in the exposed region.

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Here the lens with its capsule and ligament aids the cornea in resisting the forward pressure in active states of the oculo-motor muscles, and so prevents the bulging which would be likely to occur in the absence of such support. The lesser bulge in the case of the myope may perhaps be in some way connected with his weaker muscles.

Such are the difficulties by which the theory of the near-work origin of myopia has of late been increasingly surrounded. If in view of the consensus of opinion in favour of the theory, we have still to recognize the probability that certain cases of short-sight are really due to excessive convergence, it does not necessarily follow that the act of convergence causes elongation of the optic axis. On the contrary, such cases appear susceptible of a quite

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simple explanation from the point of view of convergence shortening. If the determiner of the synergic action of the muscles in near adaptation of the eyes is, as I have suggested, the strain on the rectus externus, it seems likely that the strain might in certain cases cause that muscle to yield a little, and by and by, if near work continued to be indulged in to excess, to undergo a measure of permanent elongation. Were this to occur, the interned position would be maintained with lessened muscular effort, the pressure on the eye would diminish, and a small amount of axial myopia might result. Whilst it is probable that this has at times been the actual course of events it will not occur very often, and when it does, will imply a somewhat feeble state of the ocular muscles. It will in fact illustrate

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the common association of short-sight with weakness. Being somewhat exceptional it will rather emphasize than abrogate the rule that strong action of muscles, whether occurring during convergence or otherwise tends to obviate myopia.

Apart from varying strength, the varying direction of the muscular pull may affect the refraction system, and this depends in the first place, as has been already stated, on the size of the eye and its more or less advanced position in the orbit, and secondly on the varying types of skull with which variations in the size and position of the eye are associated. I know of no measurements of the relative size of the barbarian and the cultured eye, but examination of skulls and of authentic drawings of the savage physiognomy favours the view that the eye of uncultured is

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definitely smaller than that of advanced peoples. The difference will have two effects. If, as seems probable, the proportion between the transverse and the axial diameters of the globe remains the same in civilized as in savage peoples, and no diminution in the curves of the lens accompanies the diminution of those of the enlarging eye, the mere change of size, by causing the rays to focus before they reach the retina, will tend to produce or increase myopia. Further, and more particularly, in an eye which has undergone this secular enlargement, especially if, as seems usually to be the case it is situated further forward, and owing to the greater breadth of the civilized skull, at a greater distance from its fellow than the primitive eye, the obliqui, and probably in some cases the superior and inferior recti

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muscles, will pursue a more than usually transverse course, and will contribute, through the altered relation of their pull to the optic axis to an increase of the existing short-sight. On the other hand the eye of the savage is not only smaller, but seems also to be generally more deeply placed in the orbit, and owing to the relative narrowness of the primitive skull to be nearer its fellow than the eye of civilized man, conditions which imply a more antero-posterior and less transverse pull of all the oculo-motor muscles, and may have had a share in determining the character of the primitive refraction system. As the narrow head of the savage is wont to be accompanied by a narrow face, and the broader head of more advanced peoples by a broad face, the frequently noted association of short-sight with the latter type of

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physiognomy receives at least a partial explanation from the present stand-point. So too, the increasing short-sightedness of the civilized may be related to their increasing short-headedness, a characteristic which, after prolonged controversy, is now admitted to have hardly any intellectual, but may hereafter prove to have considerable ophthalmological significance.

The above results shed new light upon another much explained, but still rather obscure matter, upon the part, namely, which is played by the corrugator and orbicularis muscles in distant vision. No one doubts that main uses of these muscles are to prevent too much light from entering the eye, and, by cutting off outer less accurately refracted rays, to obviate blurring of the retinal images. As myopia, which is the chief cause of

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distance obscuration, is held to be so much more common among the civilized than among savages, and as authorities agree that these auxiliary clarifiers of the distant field are chiefly had recourse to by the short-sighted, it might reasonably have been expected that the face-markings indicating strong orbicular and corrugator action would be more pronounced in the civilized than in the savage type of face. It was, therefore, something of a surprise on examining the excellent series of ethnographic drawings at the South Kensington Museum, to find the markings much more obvious in primitive than in advanced peoples. For instance it would be difficult to imagine any more striking physiognomic contrast than that between the prominent open eye, smooth or transversely ridged fore-

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head, and slightly raised eye-brows of the Chinese, Japanese, Arabs, Persians, Italians, Egyptians, and the deep-set inconspicuous eye beneath lowering, vertically ridged brows of the Negrito, the Fuegian, the Papuan, the Niam-Niam, the Veddas of Ceylon, and the Matabili. One's first impulse was to conclude that the depressed brows and half-shut eyes thought to be characteristic of myopia, in reality indicate an emmetropic state of the refraction. Such a conclusion is, however, by no means inevitable. If a main purpose of these arrangements be to exclude light, their more marked presence in the savage might perhaps be explained by his living for the most part in sunny climates and having no hat. Among civilized peoples their greater frequency in the short-sighted is due, doubtless, to the greater

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liability of the myope, by reason of his larger pupil, to suffer from a superabundance of light, and to his instinctive effort to avoid adding the blurring from too wide an aperture to that from his myopia. In the savage, if the common opinion as to his general freedom from short-sight be well-founded, the pupil will be of moderate size even in distant focussing, and the danger of obscuration from imperfectly refracted peripheral rays will be negligible. The question then arises whether the apparent preponderance of corrugator and orbicularis action among savages is sufficiently explained by the effort to cut off superfluous light. According to Darwin these actions, while utilized in distant vision in all states of the refraction are due originally "to the habit acquired in infancy of strongly contracting the

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muscles surrounding the eyes as a protection against the congestion caused by screaming." Bowman, as quoted by Darwin, thinks that a chief use of the muscles surrounding the orbit may be "to give firm support while the globes are brought to binocular vision." From the point of view of both authors, the corrugator, orbicular and other associated muscles are primarily in some degree compressors of the eyeball, and one might surmise that something of their original function clings afterwards to their action and may contribute to their utility in distant vision. If the savage owes his apparent exemption from myopia in part to antero-posterior compression of the globe by the extra-ocular muscles, it would seem probable that the greater use which he makes of his corrugator and orbicularis

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may be designed to assist the recti in effecting that compression. This again will imply a more intimate association between the two sets of muscles than has hitherto been supposed to exist, and the reason why the highest facial types display a relative freedom from the typical forehead markings will, perhaps, be because the civilized, on account of the more transverse pull of their ocular muscles are less able than the savage to improve distant vision by muscular action, and because the relative weakness of their muscles prevents them in many cases from making the attempt.

The probability of such a co-operation of orbital with extra-orbital muscles in myopia with a view to improve distant focussing is further illustrated by the central mechanism for the innervation of

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these muscles. The motor fibres distributed to the latter group, although conveyed by the seventh nerve are now considered to come not from the nucleus of the seventh but from that of the third nerve, the oculo-motor.¹ For this no reason seems so far to have been suggested, but a probable one is now apparent. The aid of these auxiliary muscles being requisitioned chiefly in myopic conditions, it was obviously an advantage that they should be associated as regards their innervation with other muscles which have a share in averting myopia. Had they been supplied by fibres coming from the nucleus of the seventh nerve, the co-operation of the two sets of muscles would clearly have

¹ See J. Herbert Fisher's "Ophthalmological Anatomy," p. 28.

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been less perfect than it is under the existing arrangement.

The foregoing conclusions, provisional and speculative as they obviously are, at least indicate a direction in which we must work if we would rebuild our battered ophthalmological dynamics. Implying that among primitive peoples distant focussing, so far from being a state of rest, is in many cases a state of high muscular activity, they suggest that as a smaller correction of myopia is needed for near than for distant work, the effects of convergence in the short-sighted savage may differ from those which are normally met with in the civilized. Convergence, that is to say, may here cause not apparent diminution, but apparent magnification of objects, and may change the focus as it would be changed not by a divergent but

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by a convergent lens. To ascertain whether these differences actually occur is a task which may profitably engage the attention of those who have the opportunity of experimenting on primitive peoples.

Results

V

Results.

THE difference between the traditional theory of extra-ocular pressure and the theory explained in this essay may be summarized as follows. According to the one the pressure is exerted chiefly on the sides, according to the other it falls chiefly on the fundus of the eyeball. According to the one the fundus is bulged backwards and made more convex, according to the other it is pushed forwards and flattened. According to the one high pressures occur almost exclusively in the civilized, according to the other they are more common among savages than among advanced races. According to the one pressure is a

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cause, according to the other it is a corrector of myopia. According to the traditional view the difference between the savage and the civilized refraction system is due directly, perhaps chiefly, to the higher pressure that is alleged to occur among advanced peoples. According to the new view it is only indirectly related to muscular pressure, and is due in the main to structural differences between the two types of eye entirely independent of the muscular system, though modifying the action of the latter.

That the effects of these divergences of view upon both practical and theoretic ophthalmology must be considerable goes without saying. I have not hitherto attempted to trace them in detail, not because I thought them unimportant, but because they seemed to me to be much more

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the business of the eye specialist than of the general practitioner. Seeing, however, that the omission appears to have given rise to a certain amount of misunderstanding, and that the specialist for his part has not hitherto allowed his waning faith in the traditional theory to weaken his attachment to the traditional practice with regard to myopia, I will conclude with a brief reference to one or two of the more obvious applications of the new ideas.

In the first place I may call attention to errors from which the new theory promises to free ophthalmology. Let the reader think of the considerable number of persons who are everywhere straining their accommodation to overcome the full correction of myopia which the established doctrine encourages, and of the endless

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worry, more especially in the case of children, which the carrying out of such a prescription entails. I well remember the reiterated warnings given me by a German clergyman, with whom I lived during the Franco-Prussian war, about the danger of reading in the twilight with the book a span length from my nose. Now after forty-six years I still continue without hurt the practice which my kind mentor declared to be an infallible destroyer of the eyes. Nay, I am now a more hardened delinquent than ever before, having long ago ceased to tremble at the remembrance of his dismal prognostications. So far from regretting my youthful indifference to the optical benefits of Kultur, I often wonder from the vantage ground of my present views how many of the pale bespectacled students, I used in those far-

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off days to see in the Berlin streets, are in like happy case with myself as regards visual efficiency.

Or think again of the injury to science which must result from believing that extra-ocular pressure is highest in myopia and at the same time tends to aggravate that condition, from offering in explanation of an imaginary accommodation diminution of objects an unproved theory about the association of impressions of distance with varying muscular strains, and from supposing that a doctrine, which implies that myopia when once started must progress without limit, can be of any use as an explanation of the strictly limited myopia of experience. Against these disadvantages place the satisfactory results yielded by the theory of pressure shortening. Consider the light which is shed

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on the incidence of short-sight by recognition of the immunity afforded by strength, and of the co-operation of the corrugator and orbicularis with the recti muscles with a view to securing that immunity. Think how the theory of convergence shortening of the optic axis, in supplying the rationale of the maximum correction of hyperopia, and the minimum correction of myopia, merges both rules in a comprehensive injunction to assist nature in her effort towards the establishment of a general evolutionary shortsightedness ; and how, in contrast with the pessimism of the common view, it assures us that the myopia, towards which mankind are advancing, is a moderate myopia whose progress must before long be arrested, when the diminution of pressure accompanying the change from

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barbarism to culture reaches its inevitable limit.

Consider again the benefits, which may be destined to result from the application of the new views to pathology, when, instead of looking at the ocular muscles as we have hitherto done only in relation to their mechanical effects, we come to study their influence upon the nutrition of the ciliary region and upon the evolution of diseases like cyclitis and glaucoma, in which the strains, to which the corneo-sclerotic junction is subjected during movements of the eye, seem to be especially implicated. It is a remarkable fact that convergence pressure, while it has been thought capable of changing the shape of the eyeball, seems never to have been looked upon as having any relation to conditions in which the pressure of the

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intra-ocular fluids is increased. One cannot help thinking that the fact may be connected with the pressure elongation theory, and with the tendency of glaucoma to be associated with the short eye, and with hyperopic rather than myopic states of the refraction, conditions in which, according to the common but erroneous opinion, muscular pressure tends to be abnormally low. If so, it may well be that recognition of convergence shortening and of the common association among the civilized of hyperopia with strong, and myopia with weak ocular muscles, may bring a change in this respect, and may start enquiry as to whether pressure of muscles may not in certain cases be a factor in the production both of the hyperopia and of the increased tension of glaucoma.

If it be true, as some maintain, that the

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cause of the latter symptom is sometimes obstruction of the *venæ vorticosæ* at their passage through the sclerotic, it seems probable that strong muscular action might contribute to the obstruction by compressing the veins between outer and inner layers of fibrous tissue. It would be interesting in this connection to know with regard to excised glaucomatous eyes, whether their antero-posterior measurements are above or below the average of health, and whether there are cases in which the increased tension begins in the vitreous and passes thence to the anterior chamber. Were the general progress towards myopia to lead incidentally to a lessened prevalence of glaucoma and allied conditions, the fact might afford some consolation even to those who are most disposed to lament the progress.

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Nor, in weighing the new against the old ideas, need we be disturbed by the discovery that it is not so much increased effort of convergence as slowly diminishing activities of all the ocular muscles, which is more and more differentiating the sight of civilized from the sight of primitive man. If, as seems probable, the change is of the nature of an adaptation, the presumption will be that, what disabilities it may for the moment entail, the type of vision, which it is gradually setting up, will be the best which present circumstances and the exigencies of the near future will admit of. It is true indeed that myopia is a serious disadvantage as regards the prosecution of the most popular of present day industries. For my part I do not doubt that the results of recruiting large numbers of the

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short-sighted for the army have been fully as unsatisfactory as might reasonably have been anticipated. There is in fact nothing for which myopia so fatally disqualifies as it does for war, and one can readily understand the extreme uneasiness with which the Germans look upon their growing liability to the defect, as offering a grave menace to their schemes of universal conquest and pan-German Weltpolitik. That the state of progressive inanition, in which the policy of their rulers has landed them, will aggravate the general short-sightedness and cause a boom in the spectacle trade, goes without saying. Those of us on the other hand, who think that physical force will play a comparatively subordinate part in the advance of the nations towards a more stable culture, will contemplate the increasing prevalence of myopia with entire

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equanimity. For the few who are engaged in certain rather specialized occupations, a powerful alert focussing system is no doubt an extremely valuable endowment. For the great majority, it suffices to have good comparatively effortless sight, such as is afforded by a moderate myopia, at ordinary working distances, and to make use of a divergent lens on the not very frequent occasions when it is of importance to see distant objects clearly. Distances between one foot and twenty feet can for the most part be negotiated without difficulty by the short-sighted by their powers of locomotion. The loss entailed by disuse of the ciliary muscle is not inadequately compensated by freedom from all sense of effort, and ability to spend many hours at a time in employments which subserve the acquisition and diffusion of the fruits of

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culture, without fear of damaging one's eyes. Even the dim or blurred character of the myope's distant vision, particularly when it ranges over fine scenery, is not without its special compensations. The futurist artist claims that his peculiar style possesses by reason of its indefiniteness a certain power of suggestion, which artists of a more conventional type miss. We need not doubt that in so doing he is expressing a genuine conviction, though many of those best qualified to judge have admitted their inability to discover in existing specimens of the vague the special merits, to which their producers lay claim. Whether the futurist's pretensions be well- or ill-founded, it has seemed to me that what he aims at accomplishing by art is in no small degree the gift of nature to the short-sighted. There is a quaint

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suggestiveness, a dreamy emotionalism, a real if elusive poetic quality in the shadowy outlines of the myopic landscape, which is apt to disappear immediately when spectacles are put on.

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